Instrument for Measuring Cryo CTE

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MIRROR TECHNOLOGY DAYS PRESENTATION

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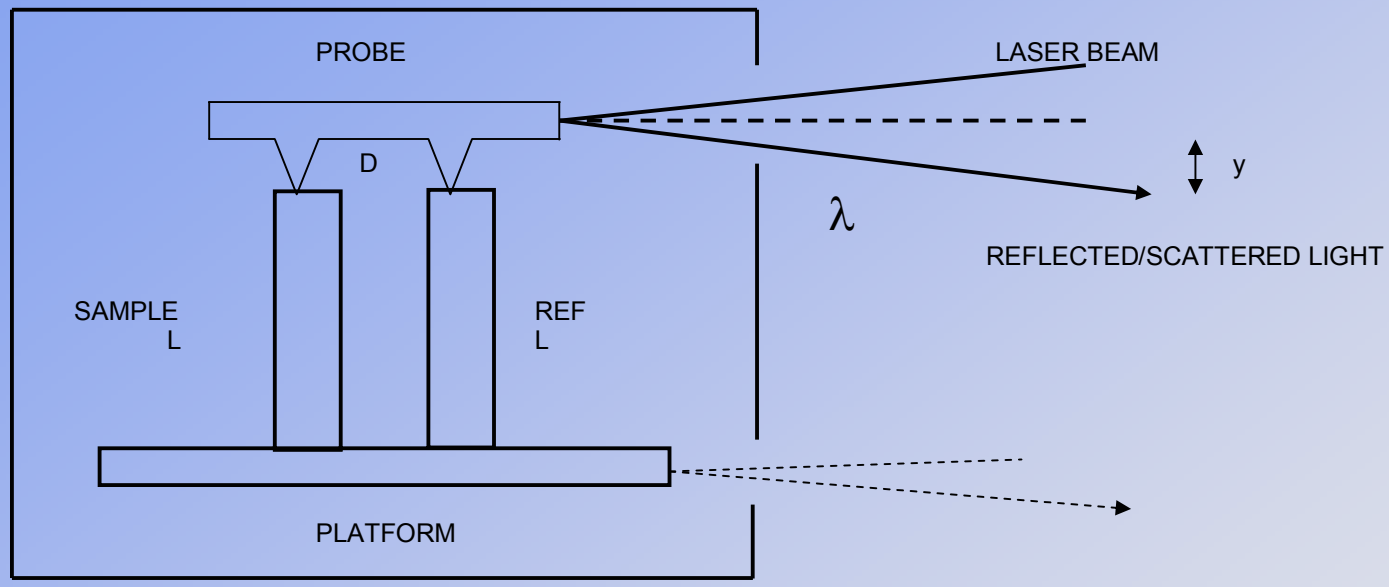
BACKGROUND

- Need of accurate material properties at cryogenic temperatures
- One important property is the Coefficient of Thermal Expansion (CTE)
- Generally accuracy of 0.1-0.5 ppm is needed to model & evaluate potential CTE non-uniformity contributions to cryogenic figure distortion
- Commercial sources – about $\pm$2 ppm
- JPL – generally much better (dependent on CTE range)

THE APPROACH



$$\Delta\theta = L(\alpha_{ref} - \alpha_{sample})\,\Delta T / D$$

$$\left(\frac{\Delta L}{L}\right)_{sample} - \left(\frac{\Delta L}{L}\right)_{ref} = -\frac{yD}{2\lambda L}$$

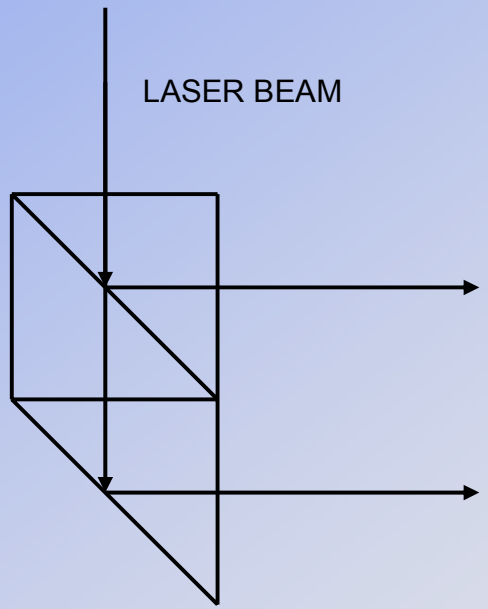
POSSIBLE CAPABILITY WITH A PSD

The 1 cm × 1 cm detector can measure 0.5 μm laser beam shifts in the cross-section. With L = 2.54 cm, *D* = 2.54 cm, `l` = 270 cm, we obtain 0.09 ppm $\Delta L/L$ sensitivity.

Further enhancement – changing `l`, *D*, optical magnification

For this example, the dynamic range of the thermal strain measurement would be 0.12 to 1600 ppm (assuming a 1 mm diameter laser spot). Or, in terms of integrated CTE (293-30 K), it would be 0.5 ppb/K to 6.1 ppm/K; this covers a very wide range of materials, from fused silica & ULE up to beryllium & silicon carbide, without any reconfiguration of the system or samples

GENERATING TWO PARALLEL LASER BEAMS

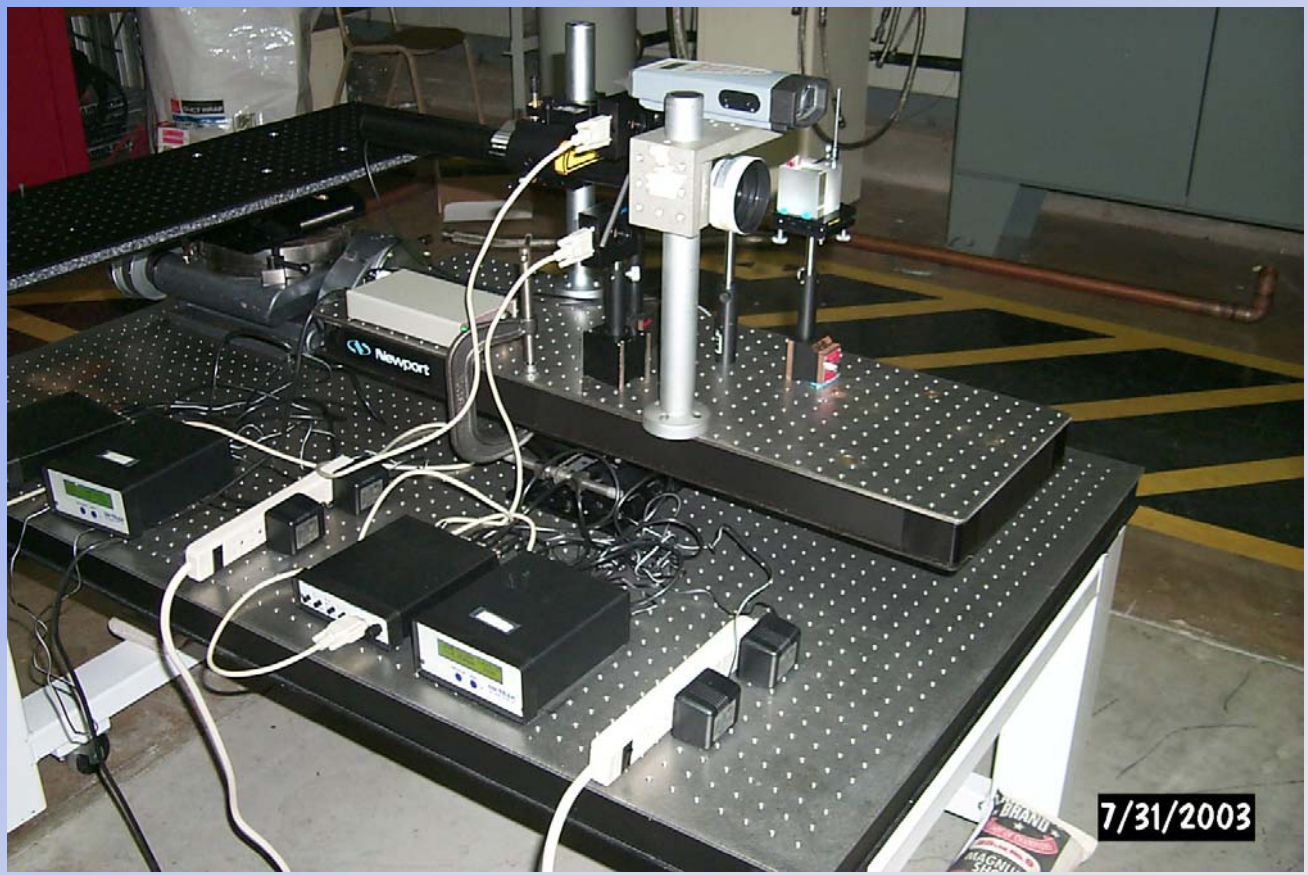


EXPERIMENTAL CONDITIONS
(MSFC 4' CRYOGENIC CHAMBER)

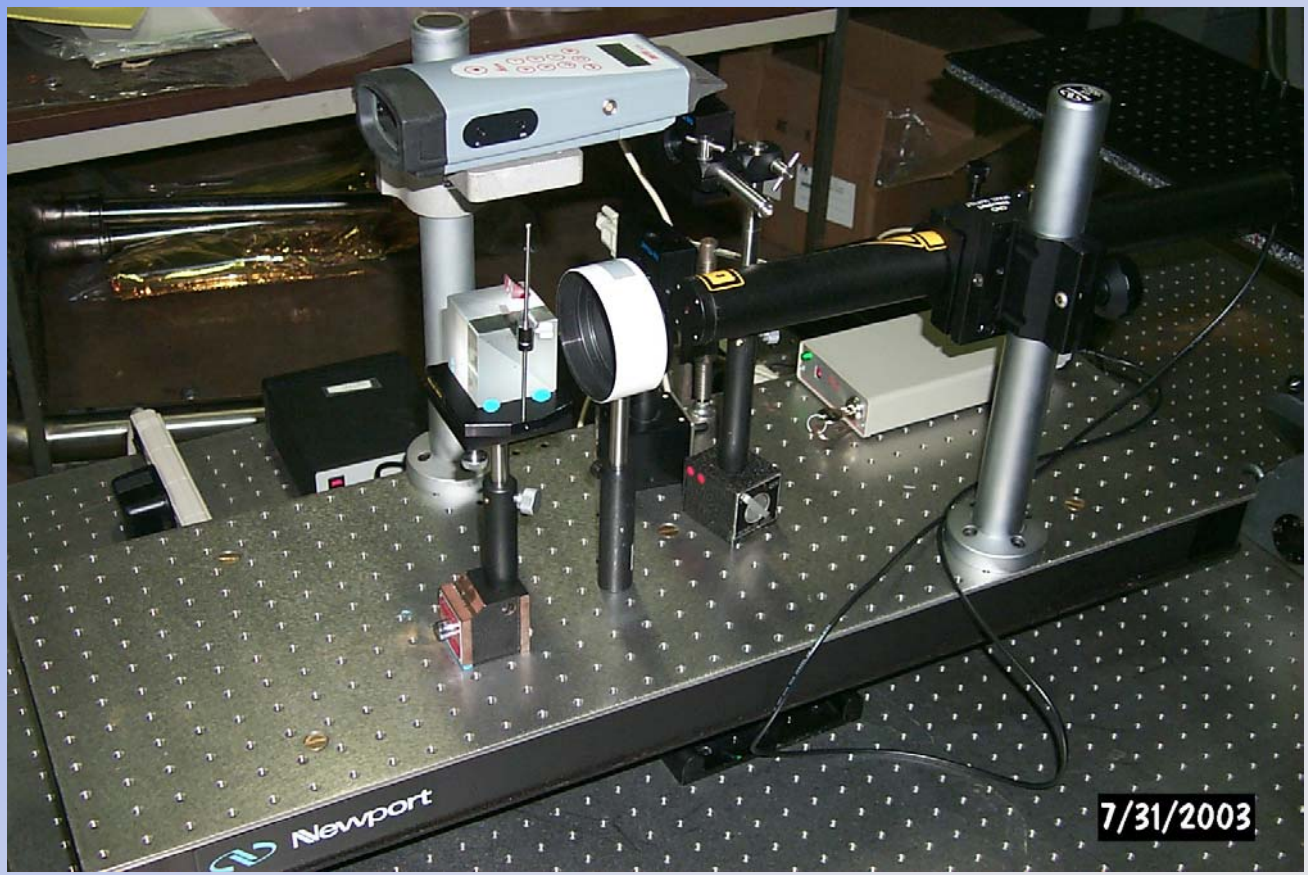
- l = 266.7 cm
- Sample (3-4 ULE) L = 2.54 cm
- Reference (Zerodur) L=2.54 cm
- Platform Zerodur, side face coated
- Reference Rod (Zerodur) D= 2.54 cm, face coated

SMALL CRYOGENIC CHAMBER AT NASA/MSFC

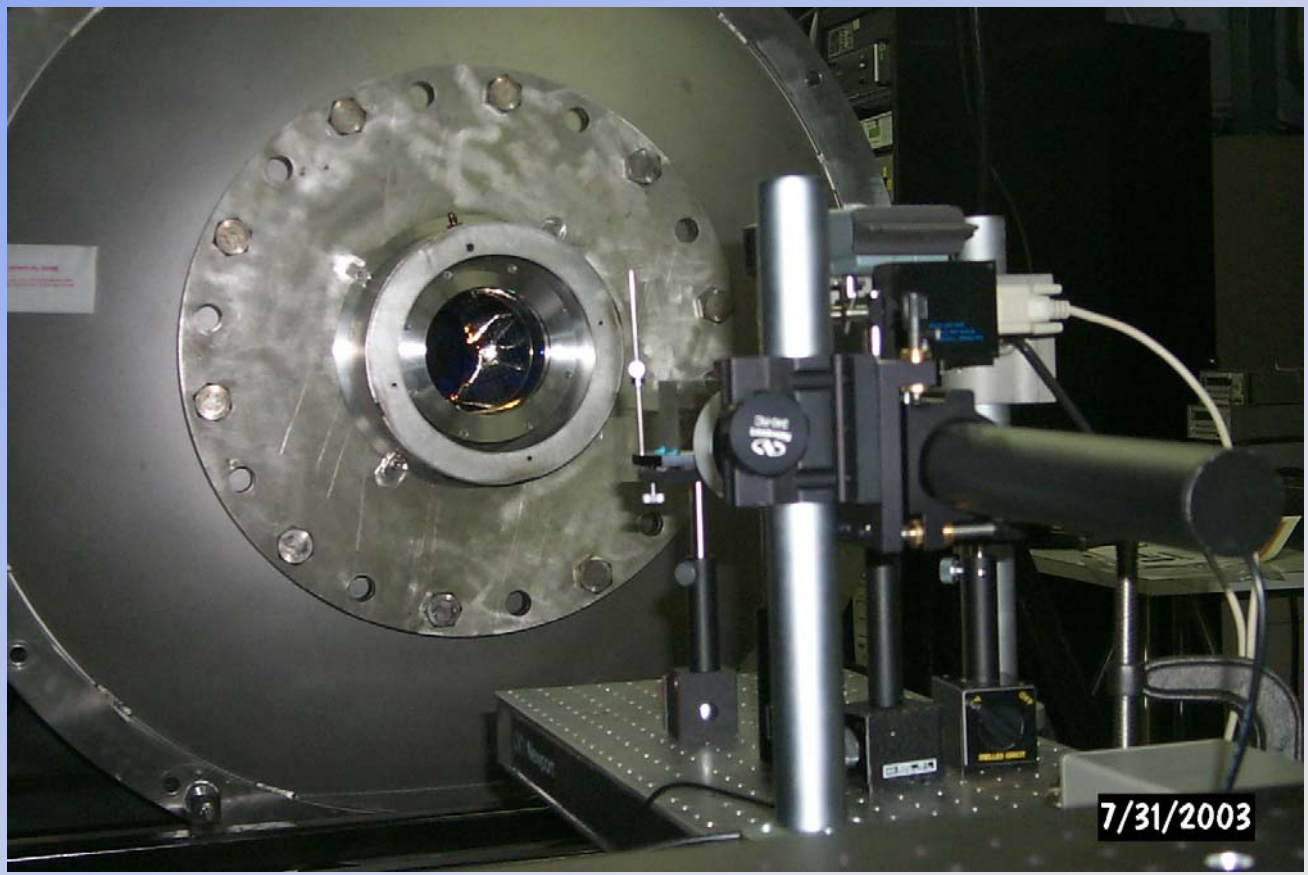
SYSTEM WITH PSD AMPLIFICATION AND READOUT MODULES



SYSTEM WITH DISTANCE MEASUREMENT DEVICE AT THE TOP



CRYOGENIC CHAMBER WINDOW FACING INCIDENT LASER BEAMS

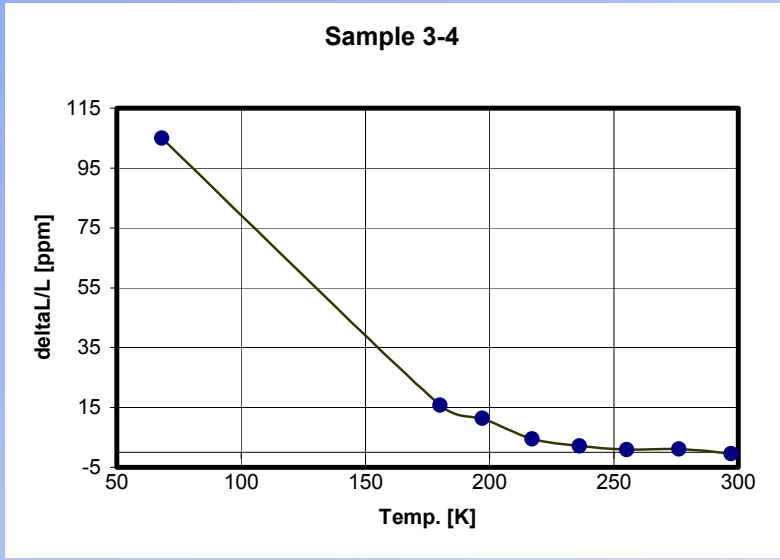


TURBULANCE EFFECTS

- On both detectors $\pm$ 0.013 mm
- Very periodic; period $\approx$ 1 minute
- Fair to assume that $\pm$ 0.001 mm or $\pm$ 1 μm or better can be obtained

INITIAL RESULTS
(September 9, 2003)

Experiment range while cooling 296.61° K – 68.222° K



Zerodur data:

LUTE Study Materials Data, Max Nein (2-27-02)

Results (from SRI data):

within 0.5 PPM for most readings; 7 % at 68.22 °K

FUTURE PLANS

- Experiments with different samples
- Temperature stabilization
- Sample/reference/probe holding
- Computer data averaging

CONCLUSIONS

It appears after some system related improvements, the calculated sensitivity can be attained. Please notice that the cryogenic chamber and laser/detector module are at room floor

ACKNOWLEDGEMENTS

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